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ANALYSIS OF THE MODIS CHARACTERIZATION SUPPORT TEAM (MCST) SOFTWARE DEVELOPMENT REQUIREMENTS

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Introduction

The Moderate-Resolution Imaging Spectrometer (MODIS) science team will be supported by three teams: (1) the MODIS Characterization Support Team (MCST), under the direction of John Barker; (2) the MODIS Science Data Support Team (SDST), under the direction of Daesoo Han; and (3) the MODIS Administrative Support Team (MAST), under the direction of Locke Stuart. Each team will play a key role supporting the MODIS Science Team. In this context, the objectives of the MCST are:

- spectral, radiometric, and geometric characterization/calibration of the MODIS instruments and resultant data product algorithm development;
- cooperative Team Member-MCST studies of discipline-related product sensitivity to calibration;
- development of MCST-related utility products.

In meeting the MCST's responsibilities, an extensive software development effort will be required. Within the first MCST objective, areas for which substantial development will occur include MODIS characterization testing, character analysis, performance modelling, and Level-1 product algorithm development. This software development will encompass four instrument copies: the Engineering, Protoflight, Flight Model 1, and Flight Model 2 MODIS instruments. The development will also include both the tilting (MODIS-T) and nadir-viewing (MODIS-N) components.

The capabilities of the MODIS instrument expand upon the achievements of a number of earlier sensors: the Advanced Very High Resolution Radiometer (AVHRR), the High-resolution Infrared Sounder (HIRS), and the Coastal Zone Color Scanner (CZCS). Additional spectral bands common to Landsat Thematic Mapper (TM) and Multispectral Scanner (MSS) have also been selected. We have therefore modelled the complexity of the MCST effort based upon a similar effort for a predecessor instrument: the Landsat Thematic Mapper (TM) protoflight model. However, as a result of the incorporation of features and capabilities from a number of earlier experiments, the MODIS instruments are somewhat more complex than the TM. If we can accurately estimate those areas for which the complexity increases relative to the protoflight TM, we will have a well-founded estimate of the level of effort required to develop characterization software and analyze the MODIS instruments.

2. Assumptions

- Hardware and COTS software have been factored as 10% of the budget.

- 50,000 lines of code have been assumed for utility program development, specifically: 5,000 for the snow-cover algorithm; 5,000 for the texture/heterogeneity algorithm; 10,000 for the scene identification mask algorithm; 5,000 for the error mask; and 25,000 for system simulations.

- Because the MCST effort is a new project, with a new[1] environment type, a team composition of from 50 to 67% senior[2] personnel is indicated[3].

- We neglect the requirements for software rehosting as a part of the MCST effort.[4]

- We assume that the MCST software development effort will emphasize the use of reusable modules. We assume that the extent of changes required for reuse, either between MODIS-N and MODIS-T or among the Engineering, Protoflight, Flight Model 1, or Flight Model 2 MODIS instruments is slight. This permits the reused modules to be costed at a relative cost of 20% of a new module.

- We assume that 50% of the MCST-developed code will be common/reused between MODIS-N and MODIS-T.

- We assume that 25% new or extensively modified code will be required to support the Engineering, Flight Model 1, or Flight Model 2 MODIS instruments relative to the Protoflight instrument software.

- We assume, as a constraint of normalization to the team leader's requested budget, that all aspects of MODIS-T are at least half as complex as the protoflight TM, and all aspects of MODIS-N are at least as complex as the protoflight TM.

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[1]The project and environment types are new when the development team has less than two years of experience with them.

[2]Senior personnel are those with more than five years of experience in development-related activities.

[3]Seniority, re-use, and rehosting assumptions are based upon the recommendations of the Manager's Handbook for Software Development, GSFC Software Engineering Laboratory, SEL84-001.

[4]The cost of rehosting software (modifying it to run on a new computer system) will range from a relative cost of 15 to 21% (plug compatible systems), 22 to 32% (similar; some key architectural characteristics shared, some different), to 35 to 50% (dissimilar; differences in most characteristics and organization).

3. Results and Conclusions

Table 1 presents the number of lines of code actually required for the pre-launch portion of the protoflight Thematic Mapper (TM). Tables 2 and 4, respectively, provide MODIS-N and MODIS-T complexity factors relative to the protoflight TM. Tables 3 and 5, respectively, scale the relative complexities for MODIS-N and MODIS-T to the Team Leader's requested budget. Tables 6 and 7 indicate the fraction of lines of code that are estimated not to be written by the MODIS-N and MODIS-T instrument contractors, respectively. Based on the fraction of development provided by the instrument contractors, and the anticipated (and normalized) complexity of the MODIS instruments, the number of lines of code required by MODIS-N and MODIS-T protoflight instruments are provided in Tables 8 and 9.

The estimated joint coding requirement for the MODIS-N and MODIS-T protoflight instruments is provided in Table 10, while the total MCST development requirement for all MODIS instruments (including the Engineering, Protoflight, Flight 1, and Flight 2 models) is provided in Table 11. Finally, Tables 12 and 13 provide the total number of lines of characterization and calibration code estimated to be developed by both the instrument contractors and MCST for all eight MODIS instruments. The 50,000 lines of utility code (and the hardware and COTS software) are not included in the total, thought they are allowed for in the budget.

Based on first principles, using the protoflight TM instrument as a baseline, the level of effort (LOE) required to perform the MCST functions would be about an order of magnitude above the requested MCST budget. This difference is directly traceable to the increase in complexity of MODIS-N and MODIS-T relative to the prototype TM. In a general sense, after normalization to the requested budget, estimates of the complexity factors suggest that it will be about twice difficult to characterize MODIS-N as MODIS-T.

The complexity estimates indicated ratios that were particularly high in terms of:

- MODIS-N Level-1 product development (due to the complexity of the instrument)
- geometric characterization for MODIS-N (multiple focal plans and spatial resolutions) and MODIS-T (30 by 34 element detector array and tilt capability)
- radiometric and spectral characterization for MODIS-N (both reflected and thermal emitted bands; special spectral filters)

TABLE 1. LINES OF CODE ACTUALLY REQUIRED PRE-LAUNCH FOR PROTOFLIGHT THEMATIC MAPPER

	Radiometric		Geometric		Spectral		Subtotal		Total
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	
Characterization Testing	25,000	2,500	50,000	5,000	500	500	75,500	8,000	83,500
Characterization Analysis	2,500	5,000	5,000	10,000	500	500	8,000	15,500	23,500
Performance Model	10,000	15,000	5,000	5,000	100	100	15,100	20,100	35,200
Level-1 Products	10,000	20,000	5,000	2,000	100	100	15,100	22,100	37,200
Total	47,500	42,500	65,000	22,000	1,200	1,200	113,700	65,700	179,400

TABLE 2. MODIS-N LINES OF CODE COMPLEXITY FACTOR (BASED ON JOHN BARKER'S ORIGINAL ESTIMATE)						
	Radiometric		Geometric		Spectral	
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch
Characterization Testing	37	37	19	19	86	86
Characterization Analysis	37	37	19	19	86	86
Performance Model	2	2	7	7	16	16
Level-1 Products	36	36	2	2	8	8

TABLE 3. MODIS-N COMPLEXITY RELATIVE TO PROTOFLIGHT THEMATIC MAPPER (NORMALIZED TO TL'S REQUESTED BUDGET)						
	Radiometric		Geometric		Spectral	
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch
Characterization Testing	200%	200%	100%	100%	450%	450%
Characterization Analysis	200%	200%	100%	100%	450%	450%
Performance Model	100%	100%	100%	100%	100%	100%
Level-1 Products	200%	200%	100%	100%	100%	100%

TABLE 4. MODIS-T LINES OF CODE COMPLEXITY FACTOR (BASED ON JOHN BARKER'S ORIGINAL ESTIMATE)

	Radiometric		Geometric		Spectral	
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch
Characterization Testing	11	11	24	24	15	15
Characterization Analysis	13	13	24	24	15	15
Performance Model	<1	<1	2	2	1	1
Level-1 Products	1	1	<1	<1	1	1

TABLE 5. MODIS-T COMPLEXITY RELATIVE TO PROTOFLIGHT THEMATIC MAPPER (NORMALIZED TO TL'S REQUESTED BUDGET)

	Radiometric		Geometric		Spectral	
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch
Characterization Testing	50%	50%	125%	125%	75%	75%
Characterization Analysis	75%	75%	125%	125%	75%	75%
Performance Model	50%	50%	50%	50%	50%	50%
Level-1 Products	50%	50%	50%	50%	50%	50%

TABLE 6. MODIS-N FRACTION OF LINES OF CODE ASSUMED NOT WRITTEN BY INSTRUMENT CONTRACTOR

	Radiometric		Geometric		Spectral	
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch
Characterization Testing	10%	50%	10%	10%	10%	50%
Characterization Analysis	20%	90%	10%	70%	20%	90%
Performance Model	10%	90%	10%	90%	10%	90%
Level-1 Products	50%	90%	50%	50%	50%	90%

TABLE 7. MODIS-T FRACTION OF LINES OF CODE ASSUMED NOT WRITTEN BY INSTRUMENT CONTRACTOR

	Radiometric		Geometric		Spectral	
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch
Characterization Testing	20%	20%	20%	20%	20%	20%
Characterization Analysis	80%	90%	80%	90%	80%	90%
Performance Model	100%	100%	100%	100%	100%	100%
Level-1 Products	100%	100%	100%	100%	100%	100%

TABLE 8. MCST-DEVELOPED LINES OF CODE ESTIMATED FOR MODIS-N PROTOFLIGHT									
	Radiometric		Geometric		Spectral		Subtotal		Total
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	
Characterization Testing	5,500	2,500	5,000	500	500	1,000	10,500	4,000	14,500
Characterization Analysis	1,000	9,000	500	7,000	500	2,000	2,000	18,000	20,000
Performance Model	1,000	13,500	500	4,500	500	500	2,000	18,500	20,500
Level-1 Products	10,000	36,000	2,500	1,000	500	500	13,000	37,500	50,500
Total	17,000	61,000	8,500	13,000	2,000	4,000	27,500	78,000	105,500

TABLE 9. MCST DEVELOPED LINES OF CODE ESTIMATED FOR MODIS-T PROTOFLIGHT									
	Radiometric		Geometric		Spectral		Subtotal		Total
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	
Characterization Testing	2,500	500	12,500	1,500	500	500	15,500	2,500	18,000
Characterization Analysis	1,500	3,500	5,000	11,500	500	500	7,000	15,500	22,500
Performance Model	5,000	7,500	2,500	2,500	500	500	8,000	10,500	18,500
Level-1 Products	5,000	10,000	2,500	1,000	500	500	8,000	11,500	19,500
Total	14,000	21,500	22,500	16,500	2,000	2,000	38,500	40,000	78,500

TABLE 10. MCST DEVELOPED LINES OF CODE ESTIMATED FOR MODIS-N AND MODIS-T PROTOFLIGHT (RE-USE FACTOR = 50%)									
	Radiometric		Geometric		Spectral		Subtotal		Total
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	
Characterization Testing	6,000	2,500	14,000	1,500	1,000	1,000	21,000	5,000	26,000
Characterization Analysis	2,000	10,000	4,500	15,000	1,000	2,500	7,500	27,000	34,500
Performance Model	5,000	17,000	2,500	5,500	1,000	1,000	8,500	23,500	32,000
Level-1 Products	12,000	37,000	4,000	1,500	1,000	1,000	17,000	39,500	56,500
Total	25,000	66,500	25,000	23,500	4,000	5,000	54,000	95,000	149,000

TABLE 11. ADDITIONAL CODING AND COMPLEXITY REQUIRED FOR MULTIPLE MODIS INSTRUMENTS		
Instrument	Complexity	Lines of Code
Engineering	25%	37,500
Protoflight	100%	149,000
Flight#1	25%	37,500
Flight#2	25%	37,500
Total complexity	1.75	261,500

TABLE 12. LINES OF CODE ESTIMATED FROM MCST AND INSTRUMENT CONTRACTOR FOR MODIS-T ENGINEERING, PROTOFLIGHT, AND FLIGHT MODELS 1 AND 2

	Radiometric		Geometric		Spectral		Subtotal		Total
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	
Characterization Testing	22,000	4,500	109,500	13,000	4,500	4,500	136,000	22,000	158,000
Characterization Analysis	3,500	7,000	11,000	22,500	1,000	1,000	15,500	30,500	46,000
Performance Model	9,000	13,000	4,500	4,500	1,000	1,000	14,500	18,500	33,000
Level-1 Products	9,000	17,500	4,500	2,000	1,000	1,000	14,500	20,500	35,000
Total	43,500	42,000	129,500	42,000	7,500	7,500	180,500	91,500	272,000

TABLE 13. LINES OF CODE ESTIMATED FROM MCST AND INSTRUMENT CONTRACTOR FOR MODIS-N ENGINEERING, PROTOFLIGHT, AND FLIGHT MODELS 1 AND 2

	Radiometric		Geometric		Spectral		Subtotal		Total
	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	Pre-Launch	Post-Launch	
Characterization Testing	87,500	9,000	87,500	9,000	9,000	3,500	184,000	21,500	205,500
Characterization Analysis	4,000	17,500	9,000	17,500	4,500	4,000	22,500	39,000	61,500
Performance Model	17,500	26,500	9,000	9,000	9,000	1,000	35,500	36,500	72,000
Level-1 Products	35,000	70,000	9,000	3,500	2,000	1,000	46,000	74,500	120,500
Total	149,000	123,000	114,500	39,000	24,500	9,500	288,000	171,500	459,500